Contactless Measurement of the Heat of Fusion of Reactive Metallic Alloys

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The heat of fusion of metallic alloys as well as the melting range is an important parameter for modeling of casting and solidification processes. Furthermore, knowledge of the heat of fusion is necessary for the evaluation of the thermodynamic functions in the stable and undercooled liquid. At high temperature or for reactive alloys such as the Zr-based metallic glass forming alloys, measurement of the heat of fusion by conventional techniques such as differential thermal analysis (DTA) or drop calorimetry is complicated by the ubiquitous presence of chemical reactions.

We describe a new measurement technique for the heat of fusion of metallic alloys based on containerless electromagnetic processing. The method was applied to eutectic Zr-based alloys as part of a program for the investigation of the thermodynamic functions of metallic formers. The experiments were performed with the containerless electromagnetic processing device TEMPUS during the spacelab missions IML-2 and MSL-1.

In the TEMPUS device a specimen is positioned by a radio (rf) frequency quadrupole field and heated by an rf-dipole field. Temperature control is performed by variation of the heater coil current and measured by a pyrometer. The enthalpy difference of the specimen between temperatures T_1 and T_2 as part of a heating or cooling curve T(t) is obtained from the power balance. The input power, i.e., Joule heating, can be obtained from the specimen resistivity and the current in the heating and positioning coil. Calibration of the coupling between the rf-fields and the specimen is perforemd by noncontact ac-calorimetry in the solid phase with known specific heat. Scaling to the temperature range of interest and, in particular, in the course of a phase transition is based on simultaneous measurment of the resistivity and diameter of the specimen. Under ultrahigh vacuum processing, the output power is purely radiative. For determination of the total hemispherical emissivity, the specific heat and the external relaxation time are measured in the pure phases just below and above T_1 and T_2, respectively. For eutectic alloys this procedure reduces to an integration of the difference in time dependent input power and radiative heat loss during the isothermal melting plateau.